IS 7354-3 (2011): Guide on Reliability of Electronic and Electrical Items, Part 3: Presentation of Reliability Data on Electronic and Electrical Components (or Parts) [LITD 2: Reliability of Electronic and Electrical Components and Equipment]

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IS 7354 (Part 3) : 2011
IEC 60319 : 1999

भारतीय मानक

इलैक्ट्रॉनिकी एवं विद्युतीय मदों की विश्वसनीयता हेतु मार्गदर्शिका

भाग 3 इलैक्ट्रॉनिकी अवयवों के विश्वसनीयता संबंधी आँकड़ों का प्रस्तुतीकरण एवं विशिष्टिकरण

(दूसरा पुनरीक्षण)

Indian Standard

GUIDE ON RELIABILITY OF ELECTRONIC AND ELECTRICAL ITEMS

PART 3 PRESENTATION AND SPECIFICATION OF RELIABILITY DATA FOR ELECTRONIC COMPONENTS

(Second Revision)

ICS 33.050.10

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

November 2011 **Price Group 7**

Reliability of Electronic and Electrical Components and Equipment Sectional Committee, LITD 02

NATIONAL FOREWORD

This Indian Standard (Part 3) (Second Revision) which is identical with IEC 60319 : 1999 'Presentation and specification of reliability data for electronic components' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Reliability of Electronic and Electrical Components and Equipment Sectional Committee and approval of the Electronics and Information Technology Division Council.

This standard was originally published in 1975 and subsequently revised in 1984. The second revision of this standard has been undertaken to bring its in line with latest technical developments by adopting the latest version of IEC 60319 : 1999.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appear to the following International Standard for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050 (191) : 1990 International Electrotechnical Vocabulary (IEV) — Chapter 191: Dependability and quality of service	IS 1885 Electrotechnical vocabulary: (Part 39) : 1990 Dependability of electronic and electrical items (*second revision*) (Part 45) : 1977 Capacitors	Technically Equivalent

The technical committee has reviewed the provision of the following International Standard referred in this adopted standard and has decided that this is acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 61360-4 : 1997	Standard data element types with associated classification scheme for electric components — Part 4: IEC reference collection of standard data element types, component classes and terms

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

GUIDE ON RELIABILITY OF ELECTRONIC AND ELECTRICAL ITEMS

PART 3 PRESENTATION AND SPECIFICATION OF RELIABILITY DATA FOR ELECTRONIC COMPONENTS

(Second Revision)

1 Scope

This International Standard gives guidance for the collection and presentation of data necessary to understand the reliability characteristics of a component. It also gives guidance to component users as to how they should specify their reliability requirements to component manufacturers. It makes no distinction between data on failures or operation without failures or faults.

Such factual information, derived from laboratory tests, should be available to the circuit and equipment designers to enable evaluation of the reliability of circuits and systems.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendment to or revisions of any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(191):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

IEC 61360-4:1997, *Standard data element types with associated classification scheme for electric components – Part 4: IEC reference collection of standard data element types, component classes and terms*

3 Definitions

For the purposes of this International Standard, the terms and definitions of IEC 60050(191) apply.

4 Requirements for presenting reliability data

4.1 General

Where possible, information should be obtained by the use of standard reliability tests. However, if some of the required data do not exist then steps should be taken to obtain them by the use of dedicated tests.

If this is not possible, then generic estimates or data from equivalent devices may be used assuming that this is stated in the data presentation.

The following or similar data should be supplied by the component manufacturer or requested by the component user: component identification, component technology, electrical specification, environmental specification, methods for selection of sample components, test related issues, data on failures.

4.2 Identification of components tested

4.2.1 General

The information supplied to identify the components should be in accordance with the relevant IEC publication for the component type under test whenever possible. If IEC publications are not available, then other component specifications should be used and the source of the specifications stated. As a minimum, the following information should be given. Only information applicable to a particular component type should be supplied.

4.2.2 Component identification

a) A description of the component type with sufficient details to uniquely identify the component type, for example N-channel V-MOS transistor. When available, specification numbers should be given.

b) The component part number. If available, a universal part number, for example stock number, should be given; otherwise a part number specific to the component manufacturer may be given.

c) Name of the manufacturer and place of manufacture. The purpose of these references is to allow access to more detailed information if required.

d) The date of manufacture or lot number or other production batch related identification. This information will allow access to other components that were produced at the same time as the sample should a problem arise.

e) The production status of the component, for example development sample, pre-production, standard production, mature technology.

f) Information regarding compliance with other recognized standards should be given whenever possible.

4.3 Component technology

a) A description of the basic component technology, for example metal film resistor.

b) A general description of the production process, for example ion beam epitaxy.

c) Packaging information, for example plastic, hermetic weld, etc.

d) Thermal resistance, for example $R_{\mathrm{th,j\text{-}a}}$, $R_{\mathrm{th,j\text{-}c}}$.

e) Complexity of circuit.

f) Method of termination, for example endcaps, DIL, SMD.

4.4 Electrical specification of components

a) Relevant information about ratings and characteristics should be supplied. These references taken from the applicable component specifications will depend on the type of test performed. For example, if power cycling tests are performed then the ratings for power dissipation should be given.

b) Information should be given about any pre-test screening the components to be tested may have undergone. The results of such screening should be given.

4.5 Environmental specification of components

Information should be given regarding the maximum environmental conditions the components can withstand, for example temperature, humidity, acceleration.

4.6 Method of selection of sample components

A description of the procedure of the sample selection should be given, for example drawn at a rate of 10 parts per week over a 10-week period or 100 pieces selected at random from a purchased lot of 10 000.

4.7 Test related issues

The test conditions should be those described in the relevant IEC publications for the components under test whenever possible. If IEC publications are not available, then other test specifications should be used and the source of the specifications stated. The following minimum information should be supplied.

a) The source of the results, for example the quality assurance department of the manufacturer.

b) A description of the test conditions used, for example the electrical, mechanical and environmental conditions. The test conditions should be identified by quoting the relevant IEC or other test specifications where possible.

c) The number of components under test. Where a component is available in a number of different values, for example resistors, capacitors, the values tested and the quantity of each value should be stated.

d) A description of the characteristic measured, for example resistance, and the measuring conditions. Where the measurement conditions are specified by IEC or other specifications, then the specification number should be given.

e) If more than one method of characteristic measurement is permissible then a description of the method used should be given. This description should contain all relevant details.

f) The test start date, duration and measurement intervals should be stated.

g) Where a delay exists between the cessation of the test and the commencement of measurements, then the time duration should be stated. The storage conditions during this delay should also be stated. Any conditioning stress applied to the components before measurement should also be stated.

4.8 Data on failures

4.8.1 General requirements

a) The number of failures observed, categorized by test conditions and type of failure, for example failure modes and parameter tolerances exceeded (see 4.8.2 a)).

b) The times at which the failures occurred or were verified.

c) Special events during testing, for example events which might have affected the results.

d) Statement about failure mechanism, if known.

e) Data from tests should be presented whenever possible. Methods for presenting such data are given in annex B.

f) If data from tests are discarded, these data and the reasons why they are not given in the presentation or results, should be given separately.

4.8.2 Additional requirements

a) Failure criteria

Failure criteria for the components (for degradation failures as well as for catastrophic failures), are normally defined by the requirements given by the specification to which reference is made in the test report. If failure criteria for the components are not given by the reference specification, they should be stated.

b) Failure rate which can be assumed to be constant

The test time of components during which the failure rate is assumed to be constant should be indicated.

c) Failure rate which cannot be assumed to be constant

The total test time can be divided into a number of separate periods and the results for each of these periods evaluated separately. The necessary time periods which have to be distinguished and the number of failures which occur during each time period should be given. If the results can be satisfactorily approximated by a mathematical function, it would be useful to present these functions, as well as the period during which they are applicable.

d) Influence of stresses

As failure rates are dependent on the type and the intensity of stress, all failure rate data should be presented with the applied stress levels. Furthermore, it can be important to know the correlation between failure rate and stress (temperature, power, vibration, etc.) and, where possible, the activation energy of the failure mechanism should be supplied. Therefore, failure rate values obtained at different stress levels should be supplied separately.

5 Presentation of reliability data

5.1 General

It is essential for component manufacturers to present reliability data for users in order to make decisions on use as well as predict failure rates and risks. The data on reliability performance and prediction should be presented in two ways, in the form of a summary and of a detailed report providing data on the various tests performed and their results.

5.2 Presentation of summary data

The summary report should contain component identification details as given in 4.2 and 4.3. A reference should be supplied for the information required by 4.4, 4.5 and 4.6.

A reference to the information required in 4.7 should also be provided and full information as required by 4.8 should be given.

It is essential that the component manufacturers provide summary data on reliability characteristics and factors affecting the failure rate prediction of the components in the component data sheets. A practical example is given in clause A.1.

It is essential for all component manufacturers to provide reliability data in a concise fashion. It should not be necessary for users to look at several documents to get the basic data. Detailed reliability test data are to be provided separately.

5.3 Presentation of detailed data

5.3.1 General

In addition to the information presented in a summary report, more detailed reliability information is often available. This information should be presented in the manner described below.

The detailed report should contain all information given in the summary report and process qualification requirements, test methods and conditions, failure rates, production process data, and package/encapsulation data.

A fill-in format covering the most interesting data as a base for reliability predictions is presented in two different parts:

– general information;

– component type specific information.

The general information part contains information needed for all kinds of components and should contain process qualification requirements, test methods and conditions, failure rates, production process data and package/encapsulation data. Component type specific information is covered by the second part where the most important parameters affecting the reliability are listed. A practical example is given in clause A.2.

5.3.2 General information

a) Identification

   Information on the component being tested, as in 4.2.

b) Qualification requirements

   Under this heading, requirements and acceptance criteria are given.

   Data required in this subclause include

   – type of tests accomplished;
   – censored/non-censored tests. If censored, state whether they are failure or time censored;
   – number of lots tested and selection method (random or other);
   – sample size of test; the accept/reject numbers to be stated.

c) Test methods and conditions applied

   Full information as described in 4.7 should be given. The following data or information is required:

   – source of the results;
   – description of test conditions;
   – number of components under test;
   – description of characteristics;
   – method of measurement;
   – test start date, duration, measurement intervals and delays.

d) Manufacturing process data

   Reliability related data useful for prediction purposes. Factors of interest on the manufacturing process of the electronic component are mainly

   – component technology;
   – screening process, method and effectiveness;
   – failure analysis results.

e) Package/encapsulation data

To identify factors influenced by weakness or strength of the component package, information is needed on

– physical outline;

– construction;

– thermal characteristics (thermal resistance, junction-case, junction-ambient).

f) Failure information

Failure analysis results are to be provided.

Failure rates found will preferably be stated in failures per 10^9 hours[1)] of operation. The value of 60 % is often used as the upper confidence level for failure rates.

In all cases, mean lifetime, failure distribution and the influence of derating should be stated. For life-limited components, an appropriate model should be suggested, for example Weibull distribution. Failure modes should be stated with percentage occurrence. Identified failure mechanisms should be stated with their associated activation energies and temperature ranges.

Data obtained from reliability tests should be presented using graphical methods whenever possible. Techniques for analysing such data and converting them to graphical form are given in annex B. The techniques of scatter diagrams, probability charts and percentile plots are recommended. Annex B also contains methods for presenting data in tabular form and producing statistical tables.

5.3.3 Component specific information needed

Examples of the specific information required for different component types can be found in IEC 61360-4.

[1)] 10^{-9} h^{-1} equals 1 FIT.

Annex A
(informative)

Examples of reports

A.1 Example of a summary report

Identification

Type:	Microprocessor specification: CE90110
Part number:	123456
Manufacturer:	XMAX, Singapore
Date:	6th week of 1996
Lot:	S5678
Status:	Standard production part; complies with CE90110
Technology	
Component technology:	HCMOS (High-density complementary metal oxide semiconductor), metallization of TiW-AlCu-TiW
Production:	Standard 1,5 µm process, single-level metal
Packaging:	160 pin plastic Japanese quad flat package
Termination:	EIAJ standard 0,65 lead pitch
Electrical specification:	IEC 4×
Environmental specification:	IEC 4×
Storage conditions:	Stored in ESD safe conditions
Methods of sample selection:	Random from one week's production
Test conditions:	
Number of lots randomly selected for testing:	3
Lot size (HTOL, THB)	300
Random sample size per lot tested	

According to the manufacturer's specification agreed with the user; 100 components under test; fully functional test as described by the manufacturer; test started 1 March 1995, three-month duration; measurement interval one week; no delays encountered

Failure information

Number of failures:	3
Failure modes:	Full functional failure (3 cases)
Failure rate:	52×10^{-9} h^{-1} at junction temperature 75°C
E_a:	0,7 eV
UCL (upper confidence level):	60 %

A.2 Example of a detailed report

Identification

Type:	Microprocessor
Specification:	CE90110
Part Number:	123456
Manufacturer:	XMAX, Singapore
Date:	6th week of 1996
Lot:	S5678
Status:	Standard production part; complies with CE90110

Technology

Material:	HCMOS (High-density complementary metal oxide semiconductor) TiW-AlCu-TiW
Production:	Standard 1,5 µm process, single-level metal
Packaging:	160 pin plastic Japanese quad flat package
Termination:	EIAJ standard 0,65 lead pitch
Electrical specification:	IEC 4×
Environmental specification:	IEC 4×
Test conditions:	According to the manufacturer's specification agreed with the user qualification requirements data
Environmental tests accomplished:	HTOL, 85 °C/85 % RH
Process-related tests accomplished:	ESD, latch-up, hot electron, gate oxide integrity, electromigration
Number of lots randomly selected:	3
Lot size (HTOL, THB):	300
Temperature cycle, thermal:	150
Accept/Reject criteria	
– Environmental tests:	1/2
– ESD:	0/1
– Latch-up:	>100 mA
– Hot electron:	Threshold voltage >50 mV
– Gate oxide integrity:	Oxide break >100 µA
– Electromigration:	ΔR/R < 30 %

Data on test methods and conditions

Test	Duration	Conditions	Standard
High. temp. oper. life (HTOL)	1 000 h	125 °C, 5,5 V	MIL 883 method 1005
Temp. hum. with bias (THB)	1 000 h	85 °C, 85 % RH	JEDEC 22B, A101
Temp. cycling	1 000 cycles,	–65/+150 °C	MIL 883 method 1010
Thermal shock	1 000 cycles	–65/+150 °C	MIL 883 method 1011

Reading points are: 168, 500, 1 000 h and 250, 500, 1 000 cycles.

Data on manufacturing process

Technology	HCMOS, HDR15, 1,5 µm, single-level metal TiW-AlCu-TiW
Screening	Burn-in 24 h, 7,0 V

Failure analysis results:

TEST	Reading	Conclusion
HTOL	168 h	Thin film oxide
	168 h	Contamination
	500 h	Poly short due to carbonized photoresistance
THB: 85/85	168 h	Corrosion
Thermal shock	100 cycles	Metal particle causing short

Package/encapsulation data

Outline	160 pin plastic Japanese quad flat package
Construction	EIAJ standard, 0,65 lead pitch
Thermal characteristics	RTH j-a = 30 K/W, RTH j-c = 7 K/W

Failure information

Number of failures:	3
Failure modes:	Full functional failure (3 cases)
Failure rate:	52×10^{-9} h^{-1} at junction temperature 75°C
E_a:	0,7 eV
UCL (upper confidence level):	60 %

Annex B
(informative)

Data analysis techniques

B.1 Primary data

The primary data comprise, for each item tested, measurements of a component characteristic obtained at sequential points of time or number of operations or cycles.

Table B.1 shows, by way of an example, the effect of an endurance test upon the gain of 50 silicon planar transistors.

Table B.1 – Primary data (example)

Component No.	Gain of individual parts at the following times					Component No.	Gain of individual parts at the following times				
	0 h	168 h	336 h	672 h	1 000 h		0 h	168 h	336 h	672 h	1 000 h
1	68	65	59	63	62	26	52	51	46	49	49
2	118	98	77	50	37	27	93	93	83	95	97
3	59	53	50	53	52	28	64	59	54	58	58
4	77	69	62	65	63	29	54	52	49	51	52
5	67	64	58	62	61	30	112	126	108	125	130
6	85	85	75	83	83	31	101	99	84	94	100
7	130	108	92	107	107	32	82	77	68	75	75
8	106	113	97	111	110	33	93	114	94	110	113
9	74	72	64	69	68	34	107	104	90	101	103
10	83	87	82	89	88	35	89	87	77	84	84
11	74	74	72	65	71	36	104	101	87	98	99
12	115	100	85	91	90	37	78	79	70	76	78
13	68	58	52	56	56	38	95	84	74	81	81
14	86	95	84	96	97	39	56	56	511	55	55
15	73	66	58	62	62	40	58	44	40	40	40
16	62	62	56	61	60	41	52	51	47	50	50
17	62	62	56	61	60	42	71	70	63	67	67
18	73	72	66	72	73	43	54	53	49	52	52
19	50	46	42	44	43	44	63	54	49	52	52
20	54	52	47	50	50	45	125	105	90	103	102
21	62	51	46	49	49	46	70	67	60	64	65
22	106	99	85	94	94	47	65	61	56	59	60
23	55	53	49	52	52	48	60	59	53	57	58
24	64	61	54	59	58	49	53	52	48	50	50
25	83	80	71	77	80	50	58	54	49	51	50

The presentation contains the full information available of an endurance test through measurements of each component tested. It is the basis for all numerical and graphical methods of presentation of drift behaviour described hereinafter. Frequently, measurements are not provided in the form of a table, but rather processed by analogue-to-digital converters whose outputs are data that will permit the use of a computer for numerical and graphical evaluation. Where the number of specimens tested is large, the table becomes too complex to conveniently provide an overall view of changes in component characteristics.

B.2 Graphical methods

Graphical methods are generally more illustrative than tabulated numbers. They give the distribution or time dependence of measurements at a glance and permit the assessment of mean values and type of distribution, as well as extrapolation of a time dependence without any mathematical effort.

B.2.1 Scatter diagram

A scatter diagram shows a relationship between measurement variables (example in figure B.1)	
Advantages – Component identity is retained. – Additional results can be easily added.	Disadvantages – The method is suitable for application only to "before or after" results. It cannot be used satisfactorily to show the pattern of continuing changes over a period of time. – It gives only a very crude idea of the distribution of the characteristics. – The sample size has to be given separately.

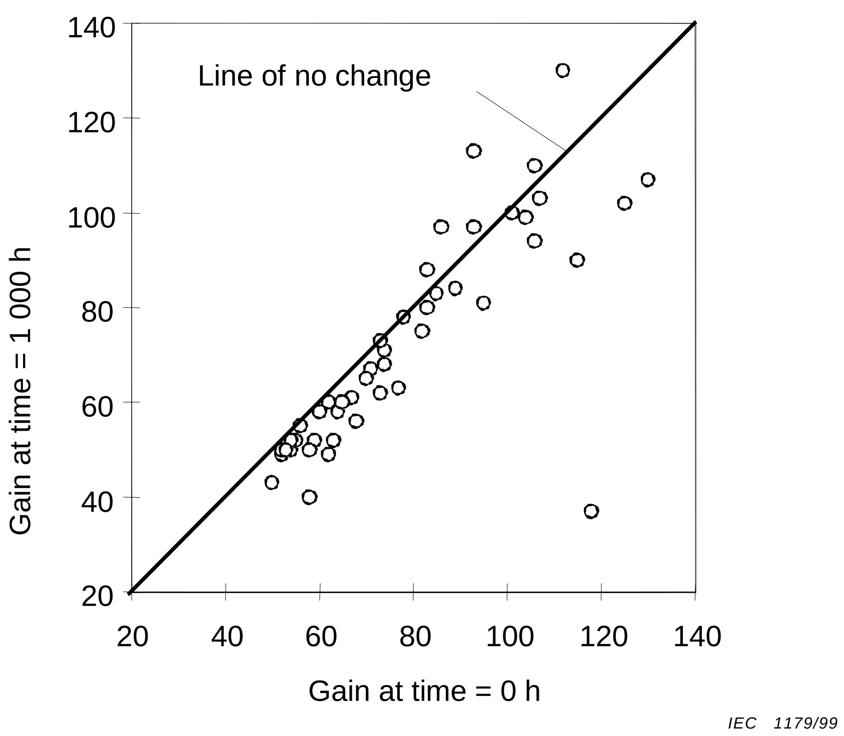

Figure B.1 – Scatter diagram plot (example)

B.2.2 Probability charts

A graph paper with the grid along one axis ruled so that a given distribution function can be plotted as a straight line against the variable as abscissa (example in figure B.2).

Advantages	Disadvantages
– The method shows clearly the extent to which the distribution of characteristics (for example the Weibull distribution) departs from normality and the way this changes with time. – It is suited to samples of all sizes (n ≥ 5). The results from very large samples can be plotted conveniently.	– Component identity is lost. – Additional results cannot be added. – The method is suitable for application only to "before or after" results. – The sample size should be given separately.

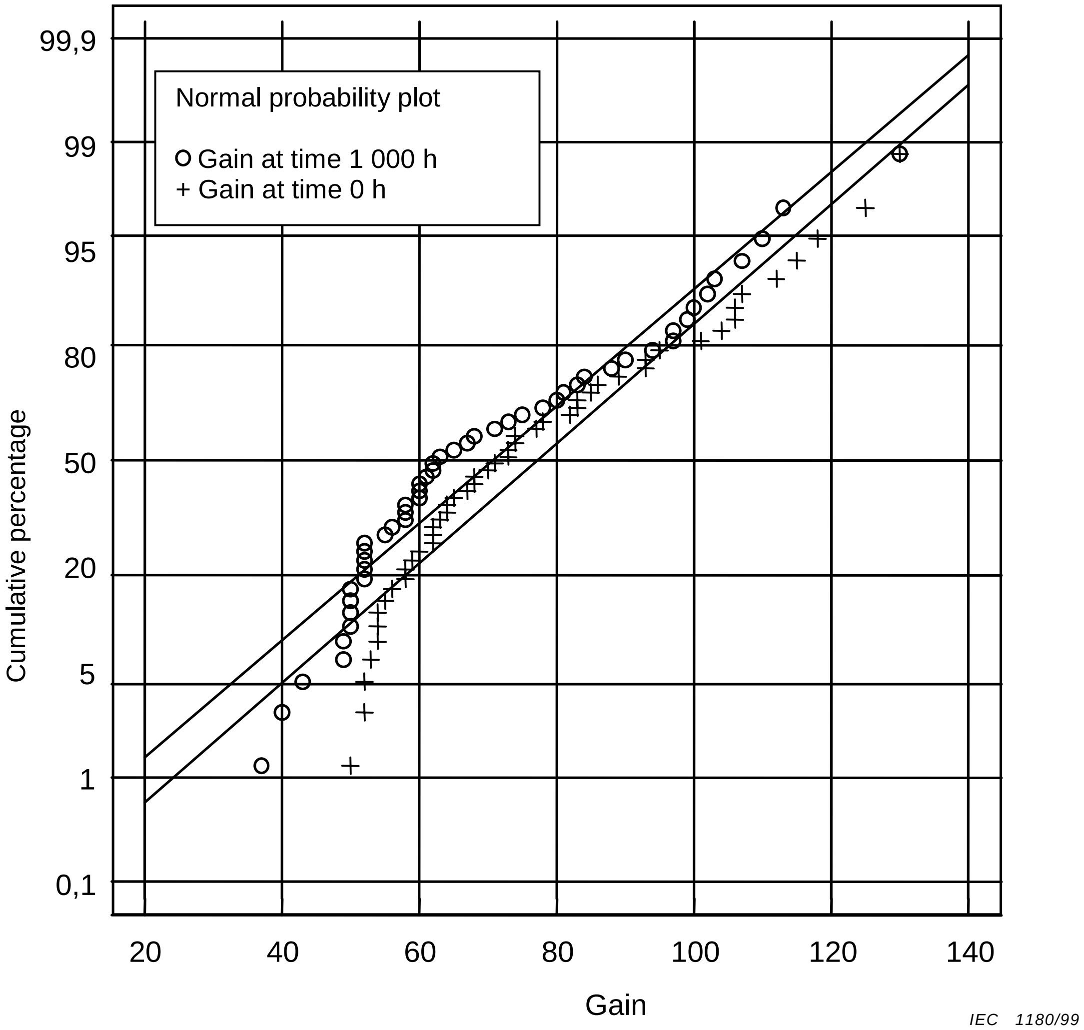

Figure B.2 – Probability chart plot (example)

B.2.3 Percentile plot

The percentiles are useful for looking at the frequency distribution of large data sets. A percentile is a value below which a certain percentage in a sample falls. Data frequently are summarized using the percentiles. A percentile plot shows changes in mean and distribution of consecutive samples (example in figure B.3).

<u>Advantages</u>

– The method is fully applicable to the representation of continuous changes over a period of time. It is not restricted to "before or after" results. As an endurance test on a particular sample continues, further results for longer times can be readily added.

– It is applicable to all small sample sizes from 10 upwards. Curves cannot cross. The final graph is no more complex for large samples than for small.

– The shape of the distribution of the characteristics at any time can be estimated from the relative distances of the percentile lines. If necessary, the results at a particular time can be replotted on probability charts.

– An estimate can be made of the curve relating percentage failed to time for any specified degradation failure limit.

– Preferred percentiles, for example 5th, 10th, 50th, 90th and 95th, could be established for all parts, assisting comparison.

– Although percentile information is usually presented graphically, it can also be given in a tabular form.

<u>Disadvantages</u>

– Component identity is lost.

– Fine details of the distribution of the characteristics is lost.

– Results from additional samples cannot be easily added. The method is not, therefore, very suitable for representing endurance tests in which results from different samples are continuously aggregated.

– The sample size has to be given separately.

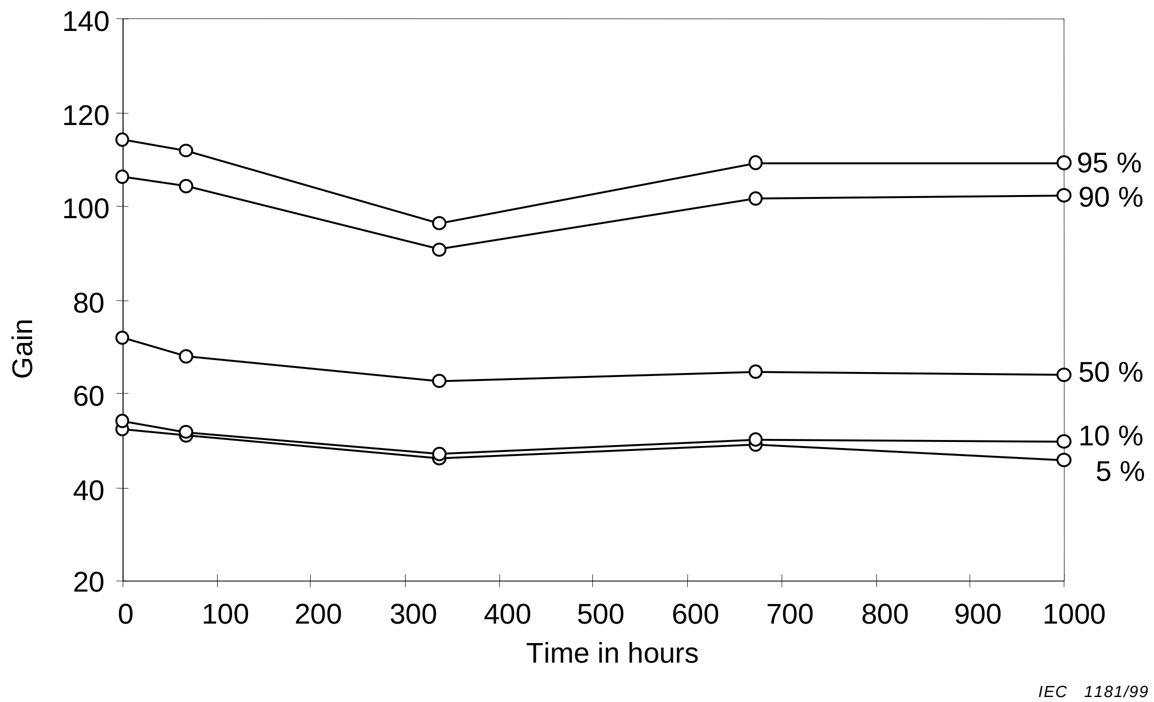

Figure B.3 – Percentile plot (example)

B.3 Numerical methods

Methods of automatic acquisition of measurements and data processing as applied to testing of large component quantities necessarily require the application of numerical methods. Whether, and to what extent, the final results are tabulated or plotted will depend on the objective of the investigation.

B.3.1 Grouped frequency distribution tables

<table>
<tr><td colspan="2">The frequency distribution is the relationship between the values of a characteristic and their absolute or relative frequencies. The distribution is often presented as a table with special groupings (classes) if the values are measured on a continuous scale. It would be preferable to use a graphical presentation such as a histogram.

The number of groups should preferably be between 5 and 25.</td></tr>
<tr><td><u>Advantages</u>
– The method is fully applicable to the representation of continuous changes over a period of time. It is not restricted to "before or after" results. As an endurance test on a particular sample continues, further results for longer times can be readily added.
– It is applicable to all sample sizes from 100 upwards. For large samples, it may be advantageous to express the frequencies as percentages of the total number of components.
– The results for a particular time can be plotted on the probability chart.
– An estimate can be made of the curve relating percentage failed to time for any specified degradation failure limit.
– Results from additional samples submitted to the same endurance test can readily be added. This is an important advantage over the percentile plot method.
– The sample size is immediately apparent.</td><td><u>Disadvantages</u>
– Component identity is lost.
– Fine details of the distribution of the characteristics is lost.
– It is not possible to establish preferred cell widths applicable to all characteristics and all parts. Here, percentile plots, for which preferred percentiles can be readily established, have the advantage.</td></tr>
</table>

Example

Table B.2 – Grouped frequencies (data from table B.1)

	Number of transistors having a gain within the specified range at the following times				
Gain range	0 h	168 h	336 h	672 h	1 000 h
Less than 40	0	0	0	0	1
40 – 59	12	17	24	21	18
60 – 79	19	15	13	13	14
80 – 99	9	10	12	10	10
100 – 119	8	7	1	5	6
Greater than 119	2	1	0	1	1
Total	50	50	50	50	50

B.3.2 Statistical parameters

In many cases, and in particular, when the form of the distribution of the values at a given point in time and for each considered characteristic is known (for instance normal distribution), it may be useful to indicate the statistical parameters of the distributions at given points in time.

Some interesting statistical parameters are the estimates of mean, median, variance, standard deviation, range and correlation coefficient.

The estimations for these statistical parameters are:

Mean	$\bar{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)$
Median	$\tilde{x} = \begin{cases} x_{(n+1)/2} & \text{if } n \text{ is odd} \\ \frac{1}{2}\left(x_{n/2} + x_{n/2+1}\right) & \text{if } n \text{ is even} \end{cases}$
Variance	$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 = \frac{1}{n-1}\left(\sum_{i=1}^{n} x_i{}^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2\right)$
Standard deviation	$s = +\sqrt{s^2}$
Range	$R = x_{\max} - x_{\min}$
Correlation coefficient between two series x and y	$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} = \frac{\sum_{i=1}^{n} x_i y_i - n\overline{xy}}{\sqrt{\left(\sum_{i=1}^{n} x_i{}^2 - n\bar{x}^2\right)\left(\sum_{i=1}^{n} y_i{}^2 - n\bar{y}^2\right)}}$

<u>Advantages</u>

– The change with time is expressed in terms of various parameters that permit a comprehensive evaluation.
– The method is fully applicable to the presentation of continuous changes over a period of time.
– It is applicable to all sample sizes.
– As an endurance test on particular components continues, further results for longer times can be added.
– The stability of the trend of changes in component parameters within the distribution is shown.
– Results can be presented graphically as well.
– Outliers and catastrophic failures are given separately.

<u>Disadvantages</u>

– Component identity is lost.
– Results from additional samples cannot easily be added.
– Fine details of the distribution of the characteristics is lost.

Example

Table B.3 – Statistical parameters (data from table B.1)

Test hours	0 h	168 h	336 h	672 h	1 000 h
Sample size	50	50	50	50	50
Mean	77,08	73,88	65,40	70,84	70,90
Median	72,00	68,00	61,00	63,50	62,50
Variance	456,61	456,68	292,82	444,83	488,62
Standard deviation	21,15	21,16	16,94	20,88	21,88
Range	80,00	82,00	68,00	85,00	93,00

Table B.4 – Correlation coefficients (data from table B.1)

Test hours	0 h	168 h	336 h	672 h	1 000 h
0 h	1	0,933	0,915	0,837	0,794
168 h		1	0,995	0,950	0,921
336 h			1	0,969	0,944
672 h				1	0,995
1 000 h					1

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